Archaeological
Institute
of America

RECENTLY PUBLISHED MEASUREMENTS OF THE PISA CATHEDRAL

It is generally known to the members of the Archaeological Institute of America that during the years since 1895, inclusive, I have published a large number of observations relating to the cathedral of Pisa. The most recent of these publications are those which have appeared in the *American Architect* of August 4, September 8, October 27, and December 1, 1909, and of January 25, March 16, 1910. The facts to be made known by this paper were published on the date of October 27. The circulation of the *American Architect* is naturally confined to the architectural profession, and the facts recently published are so important as to appear worthy also of a place in an archaeological journal.

The original observations for the levels of the foundations of the Pisa cathedral and for the related levels of the great middle stringcourse were made in 1895. They were originally entered, for record, on a ground plan of the cathedral. They were not, however, analyzed or quoted in text publication as a complete whole until the preparation of the *Catalogue of the Edinburgh Exhibition*, which was held in 1905. The circulation of this catalogue was naturally limited to the Edinburgh public and to those who visited this exhibition.

Thus, so far as the world of Christian archaeology is concerned, this present communication is the first complete account of the levels of the foundations of the Pisa cathedral and of its great middle stringcourse.

As the first point to be made is that the water-table or plinth course of the cathedral is built to the varying slopes of the earth's surface, it seems desirable to show that, although the fact is very exceptional, it is not isolated. Hence a hitherto

unpublished church is first called on for that evidence. This is the church of the Pieve Nuova at Santa Maria del Giudice near Lucca (Figs. 1–5).[1] The water-table is built to the slopes of the surface on both sides of the church. In a length of about 80 feet the church is built downhill, so to speak, to the amount of 2.31[2] feet on the north side, and 2.20 on the south

FIGURE 1.—FAÇADE OF THE PIEVE NUOVA, AT SANTA MARIA DEL GIUDICE, NEAR LUCCA (TWELFTH CENTURY ROMANESQUE).

side. The cornices are built to the true level, and the cutting of some of the blocks by which the true level was obtained is shown in Figure 3.

Now in the Pisa cathedral the length of the church is 280 feet instead of 80 feet (approximate measurement and not in-

[1] Figures 1, 2, 3, 6, 7, 8, and 9 are from photographs of the Brooklyn Museum Surveys; Figures 4 and 5 are from the *American Architect*, October 27, 1909, p. 163.

[2] The measurements, when not otherwise specified, are given in feet and decimals.

cluding the apse), but the downward slope of the water-table from the highest point at the northwest angle of the façade to the lowest point, at the southeast angle of the choir, is 3 feet (or accurately 3.02 feet).

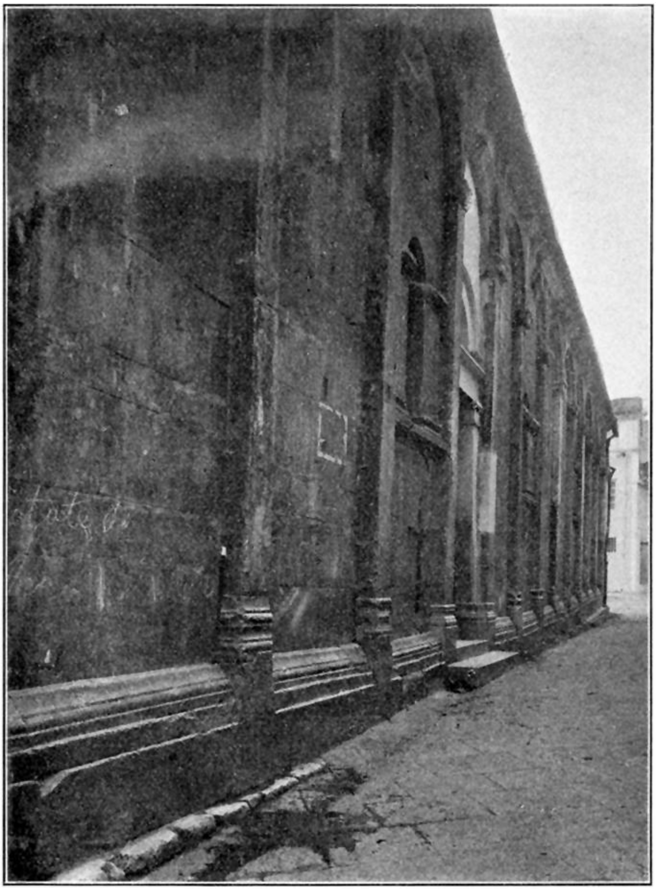

Figure 2. — The Pieve Nuova, at Santa Maria del Giudice, near Lucca. View of North Wall, looking up the Hill.

It is an astonishing fact that this has never been mentioned or figured by any of the surveyors who have published the cathedral.

That this fact is also habitually overlooked by ordinary vision is certain. It was, for instance, wholly overlooked by myself

and by Mr. John W. McKecknie, who took these levels under my direction and with my assistance, in 1895. The sum total of the levels was the greatest possible surprise to us.

The explanation of the habitual oversight lies first in the distribution of the slopes. If we assume, for instance, the usual

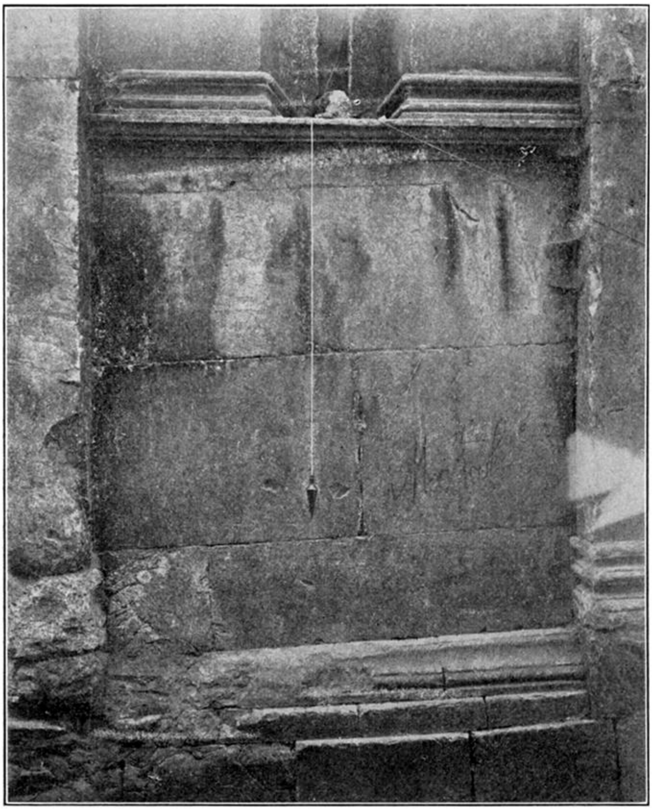

FIGURE 3. — THE PIEVE NUOVA, AT SANTA MARIA DEL GIUDICE, NEAR LUCCA.

(Detail of the North Wall. The plumb-line shows that the window ledge above the sloping water-table is level. Under the window ledge may be seen the wedge-shaped blocks by which the rectification of the slope is obtained.)

approach from the point of view taken in Figure 8, one foot of the slope (accurately 0.86) on the west side at the façade is invisible (Fig. 6), 4 inches of slope (accurately 0.31) on the west side of the south transept are also invisible (Fig. 7), 2½ inches slope (accurately 0.21) on the south wall of the nave escape

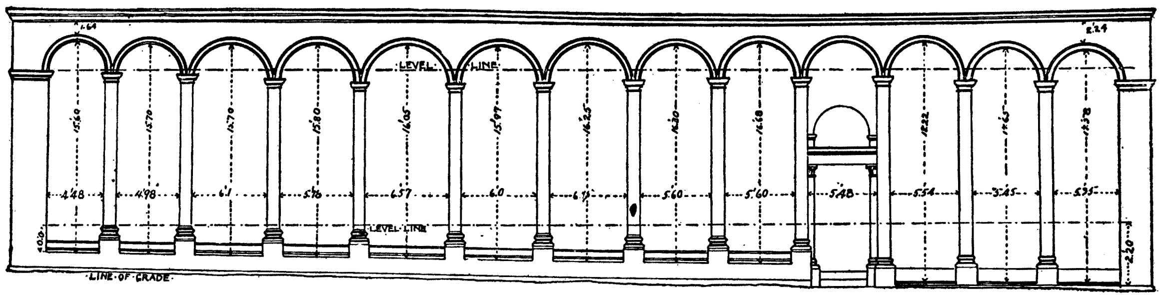

FIGURE 4.—THE PIEVE NUOVA, AT SANTA MARIA DEL GIUDICE, NEAR LUCCA.

Survey in elevation of the South Wall, showing the water-table as following the surface, the cornice as horizontal, and the heights of the pilaster capitals and arches as asymmetric. The last right-hand arch is 1.60 ft. below the level of the first left-hand arch.

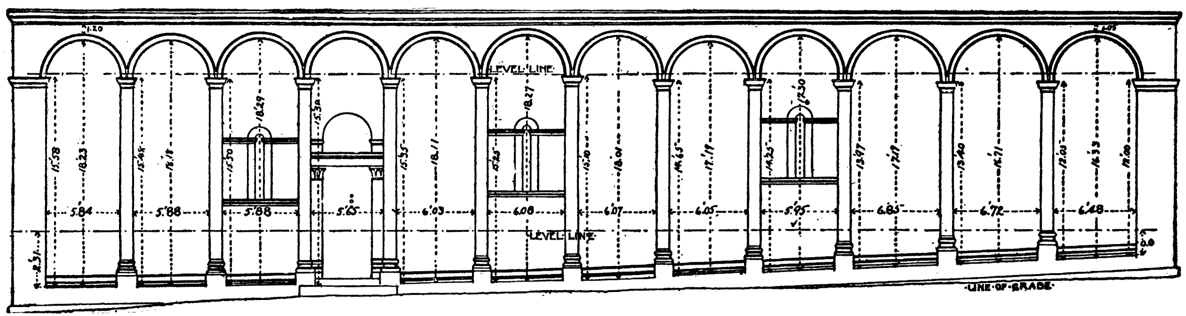

FIGURE 5.—THE PIEVE NUOVA, AT SANTA MARIA DEL GIUDICE, NEAR LUCCA.

Survey in elevation of the North Wall, showing the water-table as built to the hill slope, the cornice as horizontal, and the heights of the pilaster capitals and arches as asymmetric.

notice, of course (Fig. 8). There is a total slope of 19½ inches (accurately 1.64) on the south side of the south transept and on the south side of the choir (Fig. 8). What we have to consider first is, that out of the whole 3 feet only 1 foot 7½ inches is actually in view just here. From any other single point of view many parts of the whole slope are also beyond the range of vision. As to separate parts of the slope within the range of vision, my own experience on the façade side is, that a slope of a foot passes unnoticed. A gentle downward slope in the southeastern part of the church, from transept to apse, may be easily noticed by close attention. The fact is, however, that all surfaces slope gently as seen in perspective, and that the eye will therefore either discount gentle slopes entirely or, at least, utterly fail to realize their true amount.

At all events, the fact is that the water-table of this cathedral is built to the surface and that this surface slopes 3.02 from northeast to southwest.

At Santa Maria del Giudice the cornice and roof line are level — how is it at Pisa? Here we turn to the south side elevation of Cresy and Taylor.[1] The heights of the south side to the roof line of the outer wall are given as 57 feet 8 inches at the façade and as 57 feet 5 inches at the apse in the corresponding cornice. Hence, this roof line slopes 3 inches more than the water-table, which slopes 2.16 feet of the entire slope of 3.02, although no mention of the slopes is made by Cresy and Taylor. But how are these measures distributed? By Cresy and Taylor's elevation at the façade end it is 39 feet 3 inches to the middle stringcourse and 18 feet 5 inches to the roof cornice, but at the apse it is 37 feet 5 inches to the string and 20 feet to the corresponding cornice. In other words, the south side string is 1 foot 10 inches out of level as compared with the water-table (the difference between 39 feet 3 inches and 37 feet 5 inches), according to Cresy and Taylor. But they represent the water-table as level, whereas it slopes 2.16 feet, or 2 feet 2 inches. As we now know the true levels, it would appear from Cresy and Taylor's measures, since the south side stringcourse has 1 foot 10 inches more slope than the water-table, that it therefore slopes a sum total of 4 feet. Cresy and Taylor's heights at the east

[1] *Architecture of the Middle Ages in Italy*, pl. 4 (1829).

end are figured at the centre of the apse, whereas the Brooklyn Museum corresponding measures are taken at the southeast choir angle, but when the proper allowance is made for this difference the two results are practically identical. But Cresy and Taylor have given no measures for separate parts of the church as regards the stringcourse. If the levels for the stringcourse are computed, as they should be, from the northwest angle of the façade

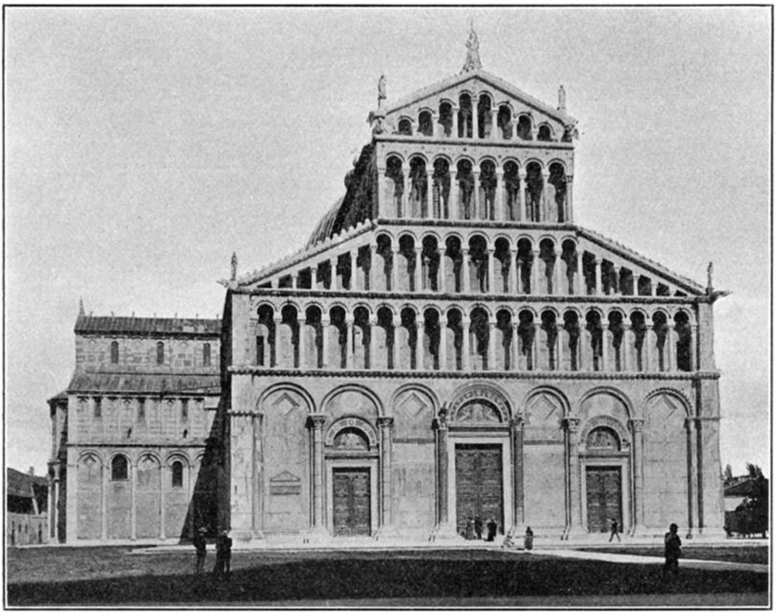

FIGURE 6.—PISA, CATHEDRAL. VIEW OF THE FAÇADE, THE NORTH WALL, AND THE WEST SIDE OF THE NORTH TRANSEPT.

(To illustrate the table of levels for the slopes of the pavement and the stringcourse.)

to the southeast angle of the choir, that is, on the line of greatest slope in the water-table, it is found that the string slopes $4\frac{1}{2}$ feet (accurately 4.46); that is to say, it slopes $1\frac{1}{2}$ foot more than the water-table, which slopes 3 feet. On the other hand, we should not forget that Cresy and Taylor's measures prove that this slope of the string is made good and rectified in the second story, which has the same height, within 3 inches, at opposite ends of the church on the south side.

We will now examine the only surveys ever made, for the

separate portions of the great middle stringcourse; namely, those of the Brooklyn Museum survey.

When the levels are taken on the north and south walls of the nave, it is found that the water-table and earth's surface slope only 3 inches on the north side and 2 inches on the south

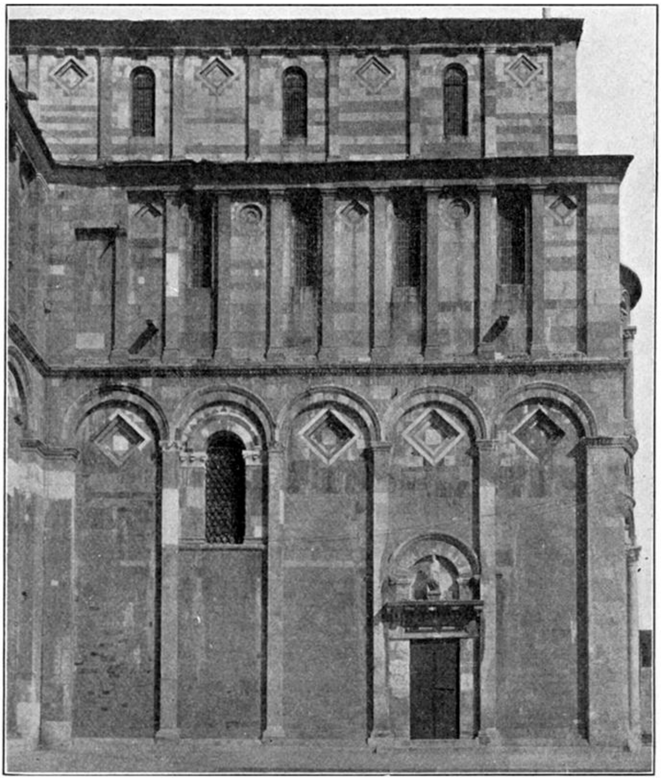

FIGURE 7.—PISA, CATHEDRAL. SOUTH TRANSEPT, WEST SIDE.
(To illustrate the table of levels for the slopes of the pavement and the stringcourse.)

side, but the corresponding strings *slope* 2 *feet to a side* (and this slope is rectified in the second story).

When the levels are taken on the *west side* of the transepts, it is found that the water-table and the earth's surface *slope down*, on both sides, away from the nave, and it is found that the stringcourses *slope up*, on both sides, away from the nave. It is also found, although the water-table slopes vary on both

sides (only 0.01 on the west side, north transept, and 0.31 on the west side, south transept), that the distance from water-table to string is the same on both sides, the rise of the string being closely $5\frac{1}{2}$ inches on each side from the line of the water-table. This result is obtained by variations in the rises of the string, which equalize and discount the variations in the downward slope of the water-table. Thus on the north transept, west side, the water-table slopes down 0.01 and the string slopes up 0.44. On

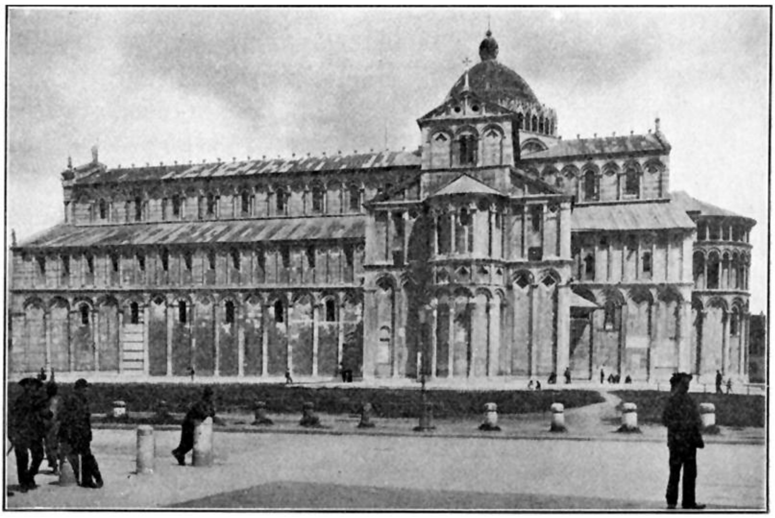

FIGURE 8.—PISA, CATHEDRAL. GENERAL VIEW OF THE SOUTH SIDE.
(To illustrate the table of levels for the slopes of the pavement and the stringcourse.)

the south transept, west side, the water-table slopes down 0.31 and the string slopes up only 0.09.

Thus when the building is considered without reference to the surface slope, the rise of the string is 0.45 ($5\frac{1}{2}$ inches) on the north side and 0.40 (5 inches) on the south side; a variation of only 0.05 (or about $\frac{1}{2}$ inch).

Beyond the points reached in this description, viz. northwest angle, north transept, and southwest angle, south transept, and moving east, the string follows the slope of the water-table, with measurements which correspond to the given slope of the given part of the building quite closely. Minor variations due to builders' errors are corrected, when they occur, in the section

next to the original error — so that the total error on the north and east sides is only 0.06 or $\frac{3}{4}$ inch. On the south side the total error is only 0.20 or $2\frac{1}{2}$ inches.

We will next consider the façade. This was the last part of the building to be completed. On the façade side the water-table and earth's surface slope down to the south 0.86

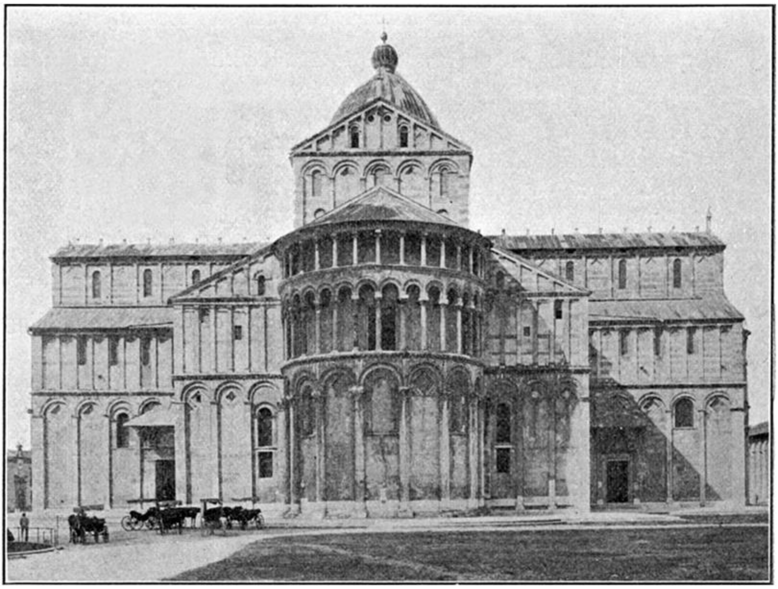

FIGURE 9. — PISA, CATHEDRAL. THE CHOIR IN PARALLEL PERSPECTIVE.
(To illustrate the table of levels for the slopes of the pavement and the stringcourse.)

($10\frac{1}{4}$ inches) and the string slopes the same way 0.56 ($6\frac{3}{4}$ inches).

All minor errors were of course corrected at this end of the building by joining the two western ends of the side string-course.

We will now rehearse and tabulate the accurate levels by which these various facts have been made known:

The accuracy of these levels is attested by the fact that they were taken by beginning at the northwest angle of the cathedral and moving thence in two directions, meeting at the south-east angle of the choir. One series of levels was taken by moving east along the north side of the church. The other series

was taken along the façade, then turning east on the south side. The simple fact that the total footings of slope, as levelled in these two different directions, corresponded exactly, at the southeast angle of the choir, is the test of the accuracy of the levels.

Tabulated Summary of Levels from the Northwest, to the Southeast, Opposing Angles of the Cathedral

The pavement falls, on the north side of the entire building and east side of the choir (the measures begin at the northwest angle):

North wall	0.26
West side, north transept	0.01
North side, north transept	0.87
North transept, east angle to choir	1.05
East side of choir	0.83
Total fall	3.02

The pavement falls, on the façade and south side of the entire building (the measures begin at the northwest angle):

Main façade	0.86
South wall	0.21
West side, south transept	0.31
South side, south transept	0.63
South transept, east angle to choir	1.01
Total fall	3.02

The stringcourse (levels in the same order for the north side of the entire building and east side of the choir):

Falls, north wall	2.09
Rises, west side, north transept	0.44
Falls, north side, north transept	1.16
Falls, north transept, east angle to choir	0.49
Falls, east side of choir	1.16
Total fall	4.46

The stringcourse (levels in the same order for the façade and south side of the entire building):

Falls, façade	0.56
Falls, south wall	2.15
Rises, west side, south transept	0.09
Falls, south side, south transept	0.63
Falls, south transept, east angle to choir	1.21
Total fall	4.46

Comparison of Levels for Each Portion of the Church and Resulting Obliquities of Construction as Distinct from Obliquities of Level

FAÇADE

Pavement slopes down to south	0.86
String slopes down to south	0.56
String rises as compared with pavement	0.30

NORTH WALL

Pavement slopes down to east	0.26
String slopes down to east	2.09
String falls as compared with pavement	1.83

SOUTH WALL

Pavement slopes down to east	0.21
String slopes down to east	2.15
String falls as compared with pavement	1.94
Variation in the obliquity of the strings on north and south sides of the nave when compared with the pavement	0.11

NORTH TRANSEPT. WEST SIDE

Pavement slopes down to north	0.01
String slopes up to north	0.44
Obliquity of the string as related to pavement	0.45

SOUTH TRANSEPT. WEST SIDE

Pavement slopes down to south	0.31
String slopes up to south	0.09
Obliquity of the string as related to pavement	0.40
Variations in obliquity of the strings on the west sides of the transepts, when compared with the pavement	0.05

NORTH TRANSEPT. NORTH SIDE

Pavement slopes down to east	0.87
String slopes down to east	1.16
Builder's error, excess downward on string	0.29

NORTH TRANSEPT EAST ANGLE TO NORTHEAST CHOIR ANGLE

Pavement slopes down	1.05
String slopes down	0.49
Builder's apparent error of underestimate in lowering string	0.56
Builder's real error of underestimate in lowering string[1]	0.27

[1] Because correcting to amount of 0.29 the previous error in the opposite direction, viz. the one made at north transept, north side.

EAST SIDE OF CHOIR

Pavement slopes down to south	0.83
String slopes down to south	1.16
Builder's apparent error of excess in lowering string	0.33
Builder's real error in excess of lowering string[1]	0.06

SOUTH TRANSEPT. SOUTH SIDE

Pavement slopes down to east	0.63
String slopes down to east	0.63
Builder's error	0.00

SOUTH TRANSEPT SOUTHEAST ANGLE TO SOUTHEAST ANGLE CHOIR

Pavement slopes down	1.01
String slopes down	1.21
Builder's error	0.20

If the order of the building reversed the order of arrangement here followed, which is probable, for it is most likely that the entire sequence of construction was from east to west, the comparisons of real and apparent error would make the corrections in the opposite direction. In that case, in considering the east and northeast sides, the first error, 0.33, was compensated for by 0.56 in reverse direction, which was 0.23 too much. The next apparent error of 0.29 in again reversed direction would make the real error 0.06 on the north side, north transept. It is evident that all minor errors could be easily corrected when it came to joining the two west ends of the north and south strings, for here it would be only a question of stretching a cord between the two points across the façade.

Conclusions

Is any philosophy of these remarkable facts possible? This question can be more easily debated by recalling a large variety of additional and related facts which have been published for the same cathedral, and for other churches which I have previously mentioned in various periodicals or catalogues.

For possible explanations I will therefore refer to the Catalogue of the recently installed Architectural Exhibition of the Brooklyn Museum, to my recent publications in the *American Architect*, and to others in the *Architectural Record*, as published in 1896 and 1897.

[1] Because variations otherwise correct error of 0.27 in opposite direction at north transept, northeast angle to northeast choir angle.

For the moment I wish rather to urge the singular importance of these particular proofs that these particular facts are themselves intended and constructive, and I wish also to call attention to the fact that these particular proofs are hitherto unpublished in complete form, with the exception mentioned.

To sum up these proofs, we have: first the correspondence of measures for corresponding facts on opposite sides of the church. Thus although the stringcourses on the north and south sides of the nave are out of level, about 2 feet on each side, the discrepancy between the two sides is only 0.11 (or a little more than one inch) when water-table and string are compared.

Again, as regards these stringcourses, there is the fact that the slope is rectified in the second story, and the crowning evidence is found in the wedge-cutting of the blocks above and below the strings, as shown in photographs, many of which have been published and all of which are on exhibition in the Brooklyn Museum.

As regards the west sides of the transepts it is apparent that accidental settlement cannot explain slopes on the same wall in contrary directions, for while the water-table slopes down, the string slopes up, on the west sides of the transept. The correspondence of measures on the two given and opposite sides, as between water-table and string, varies only 0.05 ft. (or only $\frac{1}{2}$ an inch) and the variations in amount of the slope of the string by which this uniformity is obtained are also a positive proof of intention.

As to the parts of the cathedral beyond the west sides of the transepts, it is now known that the water-table follows the slopes of the surrounding surface in every other individual part of the building. It does only the same here. It is also to be noted that the middle string to the east of the west sides of the transepts follows the general law which rules throughout the building, when the roof line of the outer wall is considered. It is shown by the measures of Cresy and Taylor, as well as by those of the Brooklyn Museum, that the roof line of the entire building is parallel with the water-table, up to the cornice of the outer wall of the nave, and its continuation in the choir. We have also seen that the measures given by Cresy and Taylor

agree with those of the Brooklyn Museum for the total obliquity of the middle stringcourse on the south side of the building, when this obliquity is compared with the line of the pavement, although the obliquities due to slope, or to following slope, in the upper alignment, are ignored. (Rohault de Fleury not only ignores the slopes of surface, but he also represents the middle stringcourse as horizontal in his elevations for the south side of the nave.[1])

In the matter of explanations, this much may be suggested. As regards the surface slopes of the water-table, it was doubtless held to be more beautiful and artistic to build this base moulding to the surface. Consider how much the building would lose if it stood on an inartistic and unornamented pile of masonry which would have raised the building 3 feet from the earth at the choir, and which would necessarily have carried an irregular front of undecorated masonry under the façade. Instead of rising from the surface, this church, like so many others, would have risen from an irregular pile of bare masonry. The undulating irregularity of the surrounding surface which now adds great beauty to the building would otherwise have involved unsightly methods of building to level.

In the Street of the Silversmiths at Pompeii the masonry and mouldings also incline almost imperceptibly with the slope of the street.[2]

As regards the obliquities of the middle stringcourse, it should be remembered that all such obliquities are translated by the eye into the optical effects to which these obliquities correspond. In photography, or in surveys, they appear abnormal, but in actual vision they result only in an effect which a shifting of position would be sufficient to produce. In actual vision, lines are never horizontal, unless they are seen in parallel perspective. In all other positions all horizontals are oblique in actual vision. To build them oblique is simply to build an effect of shifted position. When this point is once understood, it is easier to realize that the effect of optical vibra-

[1] *Monuments de Pise*, pl. XII (1859).

[2] See article 'Optical Corrections and Refinements,' in the *Dictionary of Architecture*, published by the Architectural Publication Society, printed by Thomas Richards, London, Vol. VI, p. 17.

tion or "life," which undoubtedly results, may have been the result intended.

It is my own conviction that the straightforward and bold acceptance of the irregularities incident to the use of heterogeneous material, which appears so widely in the details of this cathedral, and notably in the columns of the nave, is simply a more familiar phase of the spirit shown in building to the slope. Another illustration of this spirit is found in the careful avoidance of monotonous regularity in the masonry stripes (of white and dark green marble), a trait which is shown in all parts of the cathedral, both interior and exterior. The unfortunate results of geometrical regularity, in this particular, are shown at Siena and at Orvieto, not to speak of S. Miniato at Florence or of the Florence cathedral. (In the latter instance the irregular weathering of the surface color has mitigated the unpleasant effect of the monotonous geometrical patterns.)

Thus we may assume that the demonstrably intended asymmetries of the Pisa cathedral (and among these must undoubtedly be included those which are proven to exist by the debated levels) represent a dislike of formalism and monotony which very possibly included a preference for the vibratory optical effect which the debated asymmetries certainly produce. A distinguished New York architect, Mr. William Welles Bosworth, has recently coined the term "temperamental architecture" to cover the intentional asymmetries of mediaeval building. This term must appeal to many, as suggesting, better than any other single term, the various explanations, or the various phrasings of the same explanation, which may occur to other critics.

Once more, however, and in conclusion, the point is urged that it is not the purpose of this article to debate questions of aesthetics. These cannot long remain in doubt when the constructive facts are established. It has been the opinion of a certain school of antiquarians up to date that all differences of level in the Pisa cathedral are due to subsidence. It is in order to offer conclusive evidence on this particular head that this article is published.

WILLIAM H. GOODYEAR.

BROOKLYN, 1910.